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Study of Smart System Under Fuzzy Logic

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ABSTRACT

The statistical load survey to make the load curve is a fuzzy variable and the actions and activities may be represented by a success in the form of fuzzy membership functions to make a fuzzy set. The fuzzy set can be fuzzify and then defuzzify after some manipulations. The reliability is still a highly fuzzy variable and nothing can be said in the area of dynamic reliability. The outage rate may be found in three modes, natural outage rate (NOR) Forced Outage rate (FOR) and pollution outage rate (POR) these are also form a fuzzy set that can be defuzzified. The methods called COA, MOM, and BADD are used for defuzzification of the fuzzy space. Fuzzification may be simple but defuzzification is difficult. Fuzzy logic is a transformation like the fourier or Laplace transforms.
Here the authors find some results which give a level of satisfaction for a power plant and a large distribution network.

Keywords: Fuzzy variable, Fuzzy logic and probability, road curve and reliability.

INTRODUCTION

Reliability is a vast area of study and yet it is fuzzy variable. Very few researchers can follow real meaning of the reliability attributes to take work in their working of power networks. The authors have fuzzified the crisps and narrative models on the reliability narration and mathematical modelling. The study brings that Fuzzy techniques may provide better results in the form of sets like reliability indices such as LOP. The load curve can be used to find reliability of supply and loads to study hazards, Risks, Security and safety.

1. RELIABILITY AN EXPOTENTIAL DISTRIBUTION FUNCTION

Every power generating company has a responsibility to supply to demanded energy with minimum number of outage days called interruption in a day or a month. The less the number of outages days the more reliable is the supply system. Thus the reliability of a supply system is termed as the number of outage days per year in a mode of probability of failure. The outages per day may be one or two or three. Then the probability of failure may be found for ten minutes each time. One outage will give a probability of failure.

$$P = \frac{10}{24\times60} = 6.9 \text{ x } 10^{-3} = .0069 \quad (1)$$

and for three outages it would be:

$$P = \frac{3\times10}{24\times60} = .020833 \quad (2)$$

The reliability may be termed as

$$(I - P) = R = e^{-\lambda t} \quad (3)$$

For the first case R_1 = 0.9931and second case

$$R_2 = 0.979167 \quad (4)$$

The failure rates will be:

$$\lambda_1 = .069238 \quad (5)$$

and λ_2 = .0280082

The risk, hazard, security and safety can be found

Risk = λ R, hazard = λ^2R

Security = λ R – 1 and Safety = λ^2R-1 (6)

The up state and down state will be found

$$\lambda + \mu = 1 \text{ and } \mu = 1 - \lambda \quad (7)$$

The availability may be found as follows:

$$A = e^{-\mu t} = R$$
$$= \mu\bar{A} \text{ (R)} \quad (8)$$

The reliability is the probability of the system performing its purpose adequately for the period of time intended under the operating encountered. The above definition consists of following four important factors, probability adequate performance, time and operating conditions. As the probability is defined by two terms success and failure or non- success the reliability may be in two term as availability and non availability of units of a power plant in a specified period.

$$A + \bar{A} = ! \quad (9)$$

A = Availability and $\bar{A}$ = NOT Availability

For example a supply company has generating capacity 5200 MW and Demand 7000 MW then the deficiency will be:

(7000- 5200)/ (7000+5200) = 1800/12200 = 0. 14754 (10)

The deficiency = 14. 754 % (11)

The reliability studies may be made in the following modes :

Fuzzy variable	$\mu_{A(X)}$	λ	Risk λ R	Se	MTTF
Individual supply risk	0.921	.0823	.0758	.9242	12.1506
Interconnected supply risk	0.827	.1899	.1570	.843	5.266
Expansion planning	0.776	.2536	.1967	.8033	3.9432
Define reliability	0.927	.0758	.702	.9298	13.926
LOLP Index	0.896	.1098	.0983	.9017	9.107
Risk of LOLP	0.934	.0682	.06369	.93631	14.662

The reliability of any plant may also be improved by adding new units by expansion and Reserve capacity available, and peak load. The variation of Risk of expected load loss with different peak loads may be found for the constant Risk criterion. There is an increase of demand by 10% every year the peak load demand and demand factors and load factors are changed. The benefits of inter connection with the capacity and constant Risk evaluation are derived by reliability methods.

FUZZY LOGIC AND PROBABILITY

There are some experiments that consists of repetitions of independent trails each of which have two possible outcomes with fixed probabilities of occurring. In trails of each an experiment the distribution of two classes is discrete and of Binomial type. Consider "n" trails of each of which has a probability of success R, then probability of failure is:

$$1 - R = P = 1 \;\; -e^{-\lambda t} \tag{13}$$

The Reliability of exactly success in r trails will be R^2 The reliability of r success in r trails will be R. Thus the reliability of (n-r) failures in (n-r) trails will be

$$P^{n-r} = (1 - R)^{n-r} \tag{14}$$

The number of ways that exactly r successes 9N-r) failure can occur in n trails will be

$$n\,C_r = n\,!\,/\,r\,!\,(n - r\,!) \tag{15}$$

The reliability of exactly r success in n trails will be

$$R_r = n\,!\,/\,r\,!\,(n - r\,!)\;\; R^t\,(1 - P)^{n-r}$$

$$R_t = n\;\; C_t\, R^r\, P^{n-r} \tag{16}$$

This is the r th term of Binomial expansion

$$(R + P)^n = \sum_{r=0}^{n} \; n\,C_r\, R^r\, P^{n-r} \tag{17}$$

An experiment must have four reliability for the binomial distribution to be applicable fixed number of trails, each trail must result in a success or failure, all trails must have identical reliability of success, and all trails must be independent.

Considering, a reliability model with outcomes X_1, X_2, X_3, ... X_n and the reliability of each is R_1, R_2, R_3 .... R_n the expected value of the variable is defined as follows:

$$E(x) = P_1 X_1 + P_2 X_2 + P_3 X_3 \,............ + P_n\, X_n \;=\; \sum_{i=1}^{n} \;\; P_1 X_1 \tag{18}$$

The expected value is the weighted n can of the possible values using their reliability of occurrence as the weighting factor. There is no implication that it is most frequently occurring value of the most highly probable value

Expectation E (X) = n R

= (no of trails) (Reliability of occurrence) (19)

The Bionomial distribution can only be applied to repeated trails and multiple components if the Trial Reliabilities are identical. This situation often exists in the case of generating plant reliability evaluation involving identical units.

FUZZY LOGIC

If Fuzzy set F (z) is expressed by the Fuzzy membership functions of a subset A then $\mu\ \bar{A}(x) = 0, X \leq n$

$$(1+ (x - n)^2)^{1} \quad X > n \qquad (20)$$

The objective function X should be substantially larger than n and characterized the above membership function. The constant X should be in the vicinity of n-1 and characterized by the membership function.

$$\mu C(x) = (1 + (x - (n - 1)^4)^{-1} \qquad (21)$$

The membership function of the decision is then

$$\mu_D(x) = \mu \bar{A}(x) \cap \mu_c - (x)$$

$$= \min. \ | (1 + (x - n)^2)^{-1}$$

$$0 \quad (x - (n - 1)^4)^{-1} \text{ for } X > n$$

$$\text{For } X < n \qquad (22)$$

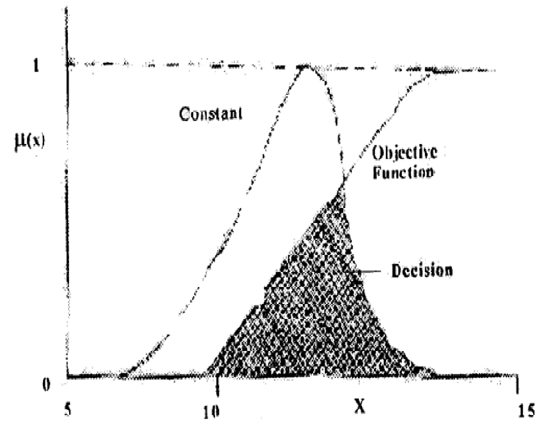

Fig. 1. Fuzzy Decision

$$|\bar{A}| \quad \int_i^n \mu \bar{A}(x) \ (dx) \text{ and } \|\bar{A}\|$$

$$= 1/n \quad \int_i^n \mu \ \bar{A} \ (x) \ dx \qquad (23)$$

One may define crisp equivalent problem by linear membership functions for full fuzzy sets involved, use of min operator for aggregating the fuzzy sets to arrive at the Fuzzy set decision. It is quite obvious that linear membership functions will not always be adequate and it can be shown empirically that the min operator is often not an appreciate model for the AND" used in decision model. One shall first consider the problem of non linear membership functions keeping the min operator as aggregates and then one shall involved what happens if other aggregating procedures are applied.

The linear membership functions used so far could all be defined by fixing two points the upper and lower aspiration levels or the two bounds of the tolerance interval. The most obvious way to handle non- linear membership functions is probably to approximate then piece wise by linear functions.

$\mu\ \bar{A}(x) = 1/2 \exp. [(x\text{-}a + b / 2)\delta /$

exp. [(x-a + b/2) δ a + b /
+ exp [- (x) - a + b / 2) δ]

Where a, b, $\delta \geq 0$
$\mu R(-x) = e^{\lambda 1} - e^{-\lambda t} / e^{-\lambda t}$ (24)

The membership function μ_c (x) and intersection
$\bar{C} = \bar{A} \cap \bar{B}$ (25)
is pointwise defined for all X λ X by
μ C (x) = min { Ā (x) , μ B (x) }

The membership function μ_D (X) of the union
$\bar{D} = \bar{A} \cup \bar{B}$ (26)
is pointwise defind for all X Y X by
μD (X) = max { $\mu \bar{A}$ (x) , μ A (x).,
$\mu \bar{B}$ (x) } (27)

The membership function of the complement of a Fuzzy set A, μ_{CA} is defined by:
$\mu c \bar{A}$ (x) = 1- $\mu \bar{A}$ (x) X Y X (28)

The fuzzy membership of the reliability attributes will be also Fuzzy Grades of truth calculated by the Fuzzy Cardinality or relative Fuzzy Cardinality as follows

$|\bar{A}| = \int_i^n \mu \bar{A}(x)\,dx$ and $\|\bar{A}\| = 1/n$
$\int_i^n \mu \bar{A}(X)\,dx$ (29)

DEFICIENCY OF LOAD

The recent demand of MPEB is 5200 MW but generating capacity available is 4400 MW.

The failure rate of deficiency will be
λ = 5200 – 4400 / 5200 + 4400 = 800/ 9600 = .0833 (30)

The probability of failure can be found from
R = $e^{-\lambda t \text{ and } R + P = 1}$
R = 92 and P = 0.0799 (31)

If the Fuzzy membership function of the demand
μ D (x) = 1 and fuzzy membership function of generation μ g (x) = 0.84615 then failure rate :
λ = (1-0.84615) / (1+ 0.84615) = .833 (32)
and reliability R = 0.92
The Risk = γ R = 0.0766 Security + 0.9234 (5)
Hazard = γ^2 r = .0063837, Safety + 0.9936
MTBF = 12.004802,
Availability A = 0.3998 (33)

Presently the expansion planning of power station are done using the percentage reserve requirement criterion. The draw back of this criterion is to compare the relative adequacy of capacity requirement for totally different system on the basis of peak loads for the some time period for each system. The reliability based expansion planning is done using constant Risk criterion For example a reserve of 800 MW will be sufficient to meet the MD of 5200 MW while 4400 MW is a generating capacity the Percentage of the Reserve would be 0.1818 or 18.18 % The adequacy of the generating may be
Adequacy = 4400/ 5200 = 0.8461 = μ A (x). (34)

Fuzzy membership function of Adequacy = μ = (x0 = .8461

The Fuzzy membership function of the Reserve may be μ_R (x) = 0.2148, Again the failure rate may be λ = μ A (x) / μ A (x) = 0.8461- 0.2148/ .8461 + .2148

$= .6313 / 1.0609 = .59506$ (35)

The combined realibility might be R = .5515

The failure rate the Reserve with respect to the adequacy may be such as to make a reliability 0.80664 the self reliability of reserve may be 0.8337.

THE LOSS OF LOAD PROBABILITY METHOD [LOLP]

The loss of load probability method [LOLP] is most widely used technique for reliability evaluation of generating systems. One can find. The reliability of generating system is evaluated for following three modes:

1. Evaluation of Reliability of individual power plants without interconnection and without expansion .
2. Evaluation of Reliability of interconnected power plants.
3. Evaluation of Reliability based on the expansion power planning of plants.

For expansion planning of power plants, it is necessary to evaluate the present Risk level without interconnection. The reliability of interconnection with a proper tie-line capacity is evaluated in second step. The outage days are reduced by interconnection.

In third step the expansion of power plant using LOLP method is made keeping the risk level of power system constant through out the planning period. It means λ_1 $R_1 = \lambda_2$

$R_2 = \lambda_3 R_3$ = Risk level constant (36)

Where R_1, R_2 and R_3 are reliabilities in the above three steps respectively and λ_1, λ_2 and λ_3 are failure rates. For the first case $\lambda_1 = 0.0833$ and $R_1 = .92$ (37)
then

$\lambda_2 R_2 = 0.76636$ (38)

The reliability may be reduced 0.886 due to the complexity of the circuit

Therefore λ_2- 0.086456 (39)

The reliability be reduced to 0.0816 and failure rate may be –
$\lambda_3 R_3 = .076636$
$\lambda_3 = .076636 / .8016 = .09560$ (40)

The constant risk criterion is not valid as the reliability is reduced and failure rates are increased. If one wishes raise the reliability, the risk will be changed. If one find the reliabilities

$R_1 = 0.95$ $R_2 = .97$
and $R_3 = .98$ then
$\lambda_1 = .0512926$ $\lambda_2 = .0304588$
and $\lambda_3 = .0202024$
The $MTTF_1 = 19.49599$,
$MTTF_2 = 32.692559$ and
$MTTF_3 = 49.4995$ years (41)

The reliability of a combined system will be raised with greater difficulties, The three risks will be

$(\lambda_1 R_1, \lambda_2 R_2, \lambda_3 R_3) = (.04872, .029545, .0197983)$ (42)

Thus risk is reduced but security is increased
$(S_1, S_2, S_3) = (.95128, 9770455, 9802037)$ (43)

Thus the system is improved for reliability. If one assumes that planning period is 8 years then $\lambda_{1,} = \lambda_2 = \lambda_3 = .125$ and $R_1 = R_2 = R_3 = 0.8824969$

The outage are reduced and the loss of load probability [LOLP] may be reduced. One can call this as Reliability of meeting the load capacity. This may be called the natural outage rate [NOR] because the life of the system will be 0.8825969.

LOAD CURVE AND RELIABILITY

The reliability of the generating plant may be found using the load curve for a year using Fuzzy logic. The curve showing the load demand of consumer against time in hours of the day is known as load curve of the hours of the day and reliability for that day be found. The curve will show the variation of the load with time in hours of the year, it is known as the annual load curve. The curve can give the following information as the electrical characteristic of the load and may provide a fuzzy reliability:

	μ A (x)	λ	Risk	Security
The variation of load during different hours of the day	0.896	.1098	.0983	.9016
The maximum demand of the day	.926	.0768	.071116	.9828
The minimum demand of the day or the year	.862	.1485	.1280	.872
Annual maximum demand	.962	.0768	.071116	.9288
Annual minimum demand	.772	.2587	.1997	0.8002
Average demand	0.889	.1176	.1045	.8954
Efficiency of the installation	0.926	.0768	.071116	.9288
Out put of the supply	0.826	.076	.06272	.9372
Input of the supply	0.962	0387	.0372	.9627

The reliability of the curve may be 7.985 and relative Fuzzy cardinality would be .7985 with a failure rate 2250 with MTTF 4.44

The other information obtained may be found

	μ A (x	λ	λR	MTTF
Load factor	.826	.19115	.1578	5.2315
Demand factor	.927	.0758	.07026	13.1926
Diversity factor inverse	0.333	1.099	.366	.909918
Capacity factor	0.876	0.1323	.1159	7.558
Station demand factor	0.929	.0736	.06837	13.586
Spinning reserve	0.912	.09211	.0840	10.856
Cold reserve	0.776	.2535	.1967	3.9447
Hot reserve	0.627	.4668	.29268	2.1422
Average demand factor	0.892	.11428	.10193	8.750
Average load	0.776	.2535	.1967	3.9447
Time of MD and duration	.927	.0758	.0702	13.1926
Time of Min demand	.798	.2256	.18002	4.4326
Total units output	0.967	.03355	.0324	29.806

The Fuzzy cardinality will be 10.566 and relative Fuzzy cardinality 0.8127692 with a failure rate 0.20730 and MTTF 4,82 years. The Fuzzy logic membership functions represent the success of the work and supplementary part is the failure, if one wishes to find load factor correctly it may be 0.826 as a grade f truth and failure probability is . 176 that is 17.69 which is very high and failure rate 0.19115 this is also high. The load curve is highly random drawn from the statistical load survey . Large number of loads may come at a time and there may be errors.

The LOLP can be found using the Fuzzy cardinality or relative Fuzzy cardinality

$| A | = \int_{i=1}^{i=x} \mu\ \bar{A}$ (x) dx and $\|\bar{A}\|$

$$= \ 1/n \int_{i=1}^{i=x} \mu\ \bar{A} (x)\ dx \qquad (46)$$

Where $\mu\ \bar{A}$ (x) is the Fuzzy membership function of the equivalent load probability density function

$$\mu\ \bar{A} (x) = e^{-\lambda t} \qquad (47)$$

This can be derived from

$$\text{LOLP} = \int_{IC}^{1C+P1} F (x)\ dx \qquad (48)$$

Where IC = $C_1 + C_2 + C_3 \ldots\ldots + C_n$ = Installed capacity

P_1 = Peak load of the system the Fuzzy space is represented as follows

	μ A (x	λ	λR	MTTF
Prbability of generating outage unit	0.927	.0758	.07026	13.1926
Probability of demand load	0.862	.1485	.1280	6.734
Probability of equivalent load	0.976	.6242	.0237	42.194
Probability of random load	0.826	.19116	.1578	5.2315
Peak load of the system	0.916	.08773	.08036	11.3986
Direcete random capacity of unit	0.776	.2536	.1968	3.9482
Capacity factor	0.896	.1098	.0984	9.10746
LOLP of long range planning	0.921	.0823	.07579	12.1506

These fuzzy membership functions are success side and not the failure side can call them the probability of the success. If one wishes to find the LOLP it may be obtained by Fuzzy relative cardinality.

$|\bar{A}| = \int_{i}^{n} \mu\ \bar{A}$ (x) dx = 7.1, and $\|\bar{A}\|$

$$= 1/n \int_{i}^{n} \mu\ \bar{A} (x)\ dx = 0.8875 \qquad (50)$$

The failure rate λ = $\log_{10}$ R/).4343 = 0. 119345

The Risk λR = .105919, Security = 1, Risk = .89408 (51)

Hazard = λ^2 R = .01264, Safety = λ^2 R – 1 = .098736

Availability = $e^{-\mu t}$ = 0. 4145

Natural outage Rate = NOR = 0.125,

Forced outage Rate = FOR = λR = . 10159

Pollution outage rate = POR = .0140625 = dp / dt = P/T (52)

DISCUSSION

s Reliability is a Fuzzy term and obtained using large number of parameters. It is highly random and obtained on the

ground of statistical information. There are some well known ideas that can find built in reliability but dynamic reliability is a still. Fuzzy variable and some attempts are made in this paper to bring out some clue of the ideas. Reliability is not as important as Risk, Hazard, Security, Safety and Availability. As a matter of fact under the heading of reliability one can find large number of parameters which are impossible to measure.

A Fuzzy cardinality, and Fuzzy relative cardinality methods are used to find the reliability. The Fuzzy grades of truth may be found using the frequency distributions, most simple is the exponential. We bull and max well to take their help to find failure rates. The failure rate is the basic parameters in the reliability heads –

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